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SOME RESULTS OF MEDICAL AND BIOLOGICAL INVESTIGATIONS IN THE SECOND AND THIRD SATELLITES

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Investigations on the Second Satellite

One of the important problems in ensuring life support for animals during flight in satellites is to produce and maintain a gaseous medium, the composition, pressure and temperature of which will be such that the basic physiological functions are not inhibited.

Dogs and other biological material can withstand relatively large fluctuations in the ambient medium; this applies to the content of oxygen and carbon dioxide in the exhaled air as well as to the pressure and temperature. For instance, dogs can withstand a reduction in air pressure to 460 mm Hg for long periods, which corresponds to an altitude of 4000 m above sea-level or a reduction in the oxygen content of the inhaled air to 15-13 percent. The concentration of carbon dioxide can increase from 0.03 to 4 percent without causing any appreciable metabolic disturbances in animals.

However, when preparing a life-support system it was essential to create the most favorable conditions for the animals. For this reason it was necessary to keep the permissible fluctuations of the parameters of the air in the capsule within very narrow limits. This is important because any appreciable deviations in the conditions of the medium from the normal limits will impose additional stresses to a greater or lesser extent which, in turn, will put additional strain on the physiological mechanisms which control the functions of the body under the new and unusual conditions. Such additional strain will produce an unfavorable background for the tolerance of overloads, weightlessness and other flight factors.

In information published in "Pravda" on September 4, 1960, it was stated that these conditions were created by means of an air-conditioning system which was built into the capsule.

It is well known that animals consume oxygen and exhale carbon dioxide and water vapor in quantities proportional to the weight and surface of their bodies. In particular, the passengers of the second satellite, Strelka and Belka, inhaled 190-200 liters of oxygen per day, exhaling 150-170 liters carbon dioxide and 250-300 g water. To maintain the gas composition of the atmosphere in the sealed capsule constant, active chemical substances were used which absorbed carbon dioxide and water vapor, and generated oxygen. These substances were placed in a special regenerative apparatus which controlled automatically the rate of absorption of carbon dioxide and water vapor and generated the required quantity of oxygen. By maintaining composition of the gas of the atmosphere constant the equipment simultaneously ensured constancy of pressure in the cabin.

In addition to carbon dioxide and water vapor, animals also exhale other substances which contaminate the atmosphere of the capsule and on accumulating in the air may prove harmful to the body. These substances include ammonia, hydrogen sulphide, volatile organic oxides, etc. Contamination of the air may also result from the operation of the apparatus and the equipment of the capsule. To purify the air from these harmful admixtures, special filters are provided in the regenerative system.

Data on the operation of the air-regeneration system and the state of the atmosphere in the cabin during flight are monitored by means of radiotelemetry which automatically transmits the necessary data to observation stations on the ground.

In addition to the above it is also necessary to maintain a given air temperature. Contrary to the views held by some people on the "absolute coldness" of interplanetary space the temperature in the capsule may vary from arctic cold to supertropical heat.

The temperature in spaceships which do not possess internal sources of heat depends on the properties of their surface, and on the capacity to absorb the energy of solar radiation and radiate solar heat into the surrounding space.

Depending on these properties, the surface of the spaceship can have a temperature as low as tens of centigrades below zero up to hundreds of centigrades above zero. Maintenance of the necessary temperature is complicated by the fact that the amount of heat from the Sun varies periodically when the satellite moves into the shadow of the Earth. Furthermore, it is necessary to take into consideration the periodical fluctuations in the quantity of heat released by the occupants of the satellite and the apparatus contained therein. These fluctuations are primarily associated with the daily periodicity of sleep and wakefulness of the occupants. Since the equipment for air-regeneration operates on "wastes" produced by the physiological functions of the animals, i. e., carbon dioxide and water vapor, the heat emitted by this equipment will also change in accordance with the level of the activity of the animals.

Heat from the cabin is removed by means of a liquid-air heat-exchanger (radiator) in which the excess heat is transmitted from the air to the circulating liquid which, in turn, gives up this heat in a special radiation heat-exchanger located outside the capsule.

Special equipment was used which enabled removal of the heat from the capsule at a rate which matched the rise in temperature during the various periods of flight so that the required temperature conditions were maintained in the capsule.

In the second Soviet satellite the animals (dogs) and the regenerative equipment were the basic source of internal heat supply.

Since their total heat release was equivalent to the heat released by a man, the creation of a system of temperature-regulation of the air in the capsule and analysis of its operation during flight are of great interest from the point of view of performing manned flight.

The processed data of the telemetric measurements carried out during the flight of the second Soviet satellite enabled an assessment to be made of the extent to which these problems had been solved during the actual flight. The percentage content of oxygen in the air of the sealed capsule was maintained continuously within the limits of 21-24 percent. The relative humidity during the first hours of flight increased gradually from 37-47 percent, probably due to the gradual introduction of the regenerative substance during operation. Later on, when the regeneration system was under steady-state conditions of operation, the air humidity was maintained at its initial level.

The air pressure of the cabin remained at the initial level without any appreciable fluctuations during the entire period of flight. The slight fluctuations in pressure at the beginning and end of flight could be explained by the changes in temperature and the percentage content of oxygen in the cabin air.

A discontinuity in the curves characterizing the pressure, oxygen content and the relative humidity between the 9th and 18th hour of the flight is due to the position of the orbit of the satellite; at that time the ground monitoring stations located on Soviet territory could not receive information from onboard the space ship.

During the first hours of flight a somewhat greater range of fluctuations and a higher temperature were observed which were due to the thermal conditions of the ship during the prelaunching period. (This satellite was launched on August 19, 1960). Later on, from the 8th to the 9th hour of orbital flight the temperature in the inhabited section of the satellite was stabilized and maintained within the limits of 16-19°C. Such narrow limits were not absolutely necessary during the flights of animals. However, in view of the proposed further development of space flights, it was considered advisable to aim immediately at creating conditions which were the most favorable for a human pilot.

The aim of the subsequent work was to improve further the systems for supporting life and testing their effectiveness from the point of view of its applicability to manned flight. In this respect, the flight of the third Soviet satellite was of great importance. Throughout the flight of this satellite necessary information on the operation of the entire equipment was obtained. These data are being processed and carefully studied.

Feeding

In the life-support system of satellites the provision of food and water to the animals is, of course, of fundamental importance. However, it is difficult to take in food and water under conditions of weightlessness. On opening containers, water and food will move freely out of the containers and be inaccessible to the animals. To overcome these difficulties a method of supplying food and water in a combined form was adopted. According to this method a food mixture was prepared containing the necessary quantities of foodstuffs and water; by adding agar-agar this mixture was given the required viscous, gelatinous consistency. The mixture adhered to the walls of the container trough, even while it was turning over and under conditions of weightlessness. These containers were stored in automatic food-dispensers which, on receiving a signal from the experimenter, dispensed the combined food mixture.

The experimental animals were given a long, preflight training, during which they became accustomed to accepting this combined mixture from the automatic food-dispenser under conditions approaching flight conditions on the satellite.

During the flight of the second Soviet satellite, the dogs Belka and Strelka were fed morning and evening. On receiving a radio-command signal the container with the food mixture opened up to each of the dogs. The opening of the container and acceptance of the food by the animals were recorded telemetrically as well as visually on a television screen.

After the space capsule returned to Earth the operation of the automatic food-dispenser was checked and the contents of the containers analyzed. The automatic food-dispenser was in the normal operating condition. The first two containers contained 20 g (Belka) and 105 g (Strelka) of food, respectively; two more containers were empty, which obviously confirmed that the dogs had eaten the food.

Thus, Belka and Strelka were fed normally during their flight with the second satellite.

Physiological, Biochemical and Cytological Investigations

On November 3, 1957 for the first time in history a living being, the dog Layka, started on its long flight into space on board the second Soviet satellite. The flight lasted for several days and during it, extensive information was collected which confirmed the assumption of Soviet scientists that it was possible for the body to adapt to long-duration flights under conditions of weightlessness.

On August 19-20, 1960 a new biological experiment in space was made. The dogs Strelka and Belka flew for 24 hrs in the second Soviet satellite and then were returned to Earth together with the capsule.

In accordance with the program of the experiment, the following factors were investigated on the experimental animals during flight: pulse rate, electrical activity of the heart (electrocardiogram) in the pectoral region, the heart tone (phonocardiagram), arterial pressure, frequency and amplitude of the respiratory movements of the thorax, the temperature of the body at two points, the motor activity of the animals, etc.

The experimental data which was obtained enabled an assessment of the general state of the bodies of the animals under conditions of weightlessness over long periods to be made, as well as making a study of the compensatory reactions of the animals, etc. For two to three months before the flight the animals were under special observation. On the eve of the flight the animals were subjected to a careful veterinary and special examination and they were passed as being completely fit. At this period the pulse rate of Strelka was 63-69 per minute and of Belka 102-104. The electro- and phonocardiograms were typical for the particular breed of animal. The maximum arterial pressure of the dog Belka was 100 mm Hg, the minimum about 40 mm Hg.

The respiration rate of the animals varied between 15-70 per minute. The animals were quiet under the conditions of limited space in the sealed capsule of the artificial satellite. The body temperature of the dog Strelka was 38.0°C - that of Belka about 37°C, which was within the normal limits.

The results of telemetric measurements have shown that on the powered section of the flight considerable changes were observed in the functioning of the cardio-vascular and respiratory systems of the animals. Due to the effects of overload, noise and vibration the pulse rate of Strelka reached 160-180 per minute, respiration became superficial and frequent (150 breathing movements per minute). In Belka the changes in the physiological functions were similar but less pronounced. In particular, the pulse rate quickened to 100 to 140 per minute. The maximum arterial pressure increased to 190 mm Hg, whilst the minimum arterial pressure remained almost unchanged. The respiratory rate of the animal was 110 per minute, reaching 240 for brief periods.

A few minutes after cessation of overload and vibration, the pulse and respiration rate dropped slightly for both dogs and about one and a half hours after weightlessness set in the pulse and breathing were comparable with those measured before the flight.

Under the subsequent influence of weightlessness, the basic physiological functions of the animals gradually returned almost to normal. During these conditions a slowing-down was observed of the pulse rate of the dogs to 74-112 per minute and the respiration rate to 24-26. Some weakening of the first and second tone of the heart was also observed. During weightlessness the characteristics of the arterial pressure of Belka returned almost to the initial level. The temperature of the body of both dogs at the end of the experiment was 37.3-37.5°C.

Of great interest are the results of investigation of the movements of the animal during flight. It was proposed to elucidate during the experiment the problem of the nature and state of the changes of the motor reactions of the animals under conditions of weightlessness. The broad formulation of the problem imposed specific requirements on techniques of the investigation. The dogs were able to move freely within certain limits. The dog was fastened in such a way that it could move consciously towards the food and fix itself in space only when its paws were unbent. In so doing, it pulled the ropes of the harness. On bending its paws, the dog lost contact with the floor and was suspended in air. Included in the harness ropes were contact potentiometric probes which recorded the force exerted by the paw. There were also probes which recorded the movement of the dogs towards the food. The movement of the dogs in the capsule was also monitored by means of two television cameras, one showing a side view and one showing the front view.

Analysis of the movements was made by comparing the television films with the information from the movement probes which was transmitted by the telemetry system and recorded in the form of curves. The latter made possible an objective evaluation of the movement seen on the films not only as regards amplitude but also as regards energy. As an example, a short description is given of the behavior of the animals on two characteristic sections of the flight of the second satellite. Thus, at the very beginning of the onset of weightlessness, the dog, suspended in air, tried to reach the floor with its paws and only when it felt support under its feet did it stretch its entire muscle system. After a short jerk the hind paws developed a constant static stress which fixed strongly the position of the dog. This proves that the dog preserved its rapid and adequate reactions to such an unusual stimulus as weightlessness.

Analysis of the television films and of the curves recorded from the telemetry information starting 12 hours from the beginning of the flight, under conditions of complete weightlessness, did not reveal any important disturbance in the coordination of movements of the dogs. The dog turned its head to its companion, sniffed at it, bared its teeth and barked. Due to absence of a support, its movements were not always rapid since the paws of the dog sometimes slid on the floor but the dog immediately corrected the error. Obviously, during such a short time it could not be expected that the various movements to be performed under a variety of situations would become quite automatic. However, a clearly pronounced tendency was observed to perform automatically certain simple and frequently repeated movements, for instance, the movements controlling the effort during fixing of the position of the body.

Immediately after landing, both dogs were subjected to thorough physiological examinations. The behavior of the animals did not differ from their usual behavior under laboratory conditions. They were active, they reacted adequately to the effects of external stimuli, they fawned, they reacted to their pet names, etc. The pulse rates of Strelka and Belka were 96-102 per minute, the respiration rates were 21-30 per minute and the arterial blood pressures corresponded to the initial values.

Immediately after the animals returned to the laboratory they were subjected to veterinary and special investigation (X-ray investigation of the thorax, biochemical examination of the blood and urine, etc.) These examinations did not reveal any appreciable changes.

Observation of the dogs over three months has shown that their flight in the satellite did not cause any unfavorable after-effects in the general state of the animals or their behavior. On November 30, the dog, Strelka, produced a litter of six puppies.

Observations have shown that the process of lactation in the dogs was quite normal. The appropriate unconditioned reflexes were fully conserved (licking of the puppies, specific reaction of the animal to the presence of strangers, unaccustomed separation from the puppies, etc.).

Data obtained during the second and third biological experiments in an artificial Earth satellite have confirmed convincingly the conclusion made after the flight of the dog, Layka, namely, that animals can adapt themselves to conditions of weightlessness over long periods. It is important that during conditions of weightlessness over long periods all the physiological functions (towards the end of the flight) should approach the initial level. This is of great scientific importance and permits sufficiently clear solutions of the problems connected with manned space flights to be derived. The results of the experiments prove that the equipment developed by Soviet scientists and engineers provides the necessary conditions for supporting life on long flights.

Undoubtedly, the results obtained from the biological experiments conducted in the Soviet satellite are unique. These experiments also show the reliability of the landing gear of the space ship. For the first time in the history of science living beings, orbited in a satellite, were brought back to Earth intact.

Another feature of these experiments was that an extensive program of investigations was carried out which included physiological-hygienic as well as biochemical, cytological, histological, microbiological and genetic investigations.

Study of the biological effects of factors associated with space flight and primarily of the biological effect of cosmic radiation is a complex and varied task, for the solution of which a variety of biological material and different methods of investigation had to be used on the second satellite.

The biological experiment in the satellite was preceded by extensive laboratory investigations on the preparation of the biological material, obtaining background information, study of the influence of individual factors which were reproduced in laboratory conditions (acceleration, vibration, etc.). Methods and techniques were evolved of ensuring the necessary conditions of living for biological material during a flight.

After returning to Earth the biological material was subjected to careful studies which are still continuing. The data obtained enable only preliminary generalizations to be made regarding the effect of various space-flight factors.

Investigation of the blood and urine of the experimental dogs, rats and mice has shown in the first instance that in the body of animals which are subjected to the effects of space flight conditions, shifts occur which are due to the so-called "stress-reactions". Several days after returning from a flight, the blood of the dogs Belka and Strelka showed a transient increase in the levels of α-globulin, serum mucoid and total protein content, as well as a decrease in the cholinesterase activity. At the same time, no appreciable and constant changes could be detected in nucleic acid metabolism.

It is of interest that during laboratory investigations of the effects of acceleration and vibration certain biochemical changes were observed in these dogs which were comparable to the results obtained after the return to Earth of the animals from their flight. At present, further biochemical data are being collected which will enable the relative importance of the individual flight factors to be assessed.

Immunological investigations of the microflora and the bactericidal properties of the skin, and the phagocytic properties of the blood of the dogs, Belka and Strelka, have shown that long-duration phasic changes occurred in the state of natural immunity, characterized by a lowering of the bactericidal properties of the skin and subsequent compensation and hydrocompensation for the disturbances in the reacting systems.

Analysis of the peripheral blood of the experimental dogs, and rats and mice has not shown any pathological changes in the white and red blood cells or in the hemoglobin content.

Cytological and histological investigations were also carried out on half-grown mice of both sexes (mongrel and pure mice of the line C_{57}Be). The haemopoietic organs, the central nervous system, the heart, lungs, etc. were studied. Compared with the controls, the experimental animals showed an increase in chromosomal aberrations of the bone-marrow cells. These changes were detected during the first days after the flight as well as during later periods. In view of this relatively specific nature of the damage caused to cells by ionizing radiations, it could be assumed that the above changes were due basically to the influence of cosmic radiation. However, the obtained results led to the more general assumption that the noted increase in the chromosomal aberrations of the bone marrow was caused by the overall effects of the various space-flight factors. Preliminary study of histological slices of various sections of the central nervous system, the spleen, the suprarenal gland, the liver and other organs did not indicate any pathological changes in the animals killed and examined during the first two weeks after return to Earth.

The investigations carried out so far do not reveal any appreciable genetic damage or physiological changes in the bacteria studied, alimentary tract bacillae of various strains, rod bacteria involved in butyric acid fermentation and staphylococci). Phages and cultures of cancerous Hela cells and skin flaps of man and rabbit which flew in space also differed little from their respective controls. Regrafting of the returned skin flaps was successfully carried out. Automatic bioelements (Translator's note: instruments which were developed specially for recording automatically the physiology and biochemistry of micro-organisms) with cultures of butyric acid fermentation bacteria functioned in space satisfactorily according to the planned program and the obtained data indicated that the bacteria were viable under conditions which were unusual to them.

It is well known that on the second Soviet satellite genetic investigations were carried out on a large volume of varied biological material.

The Soviet scientists R. L. Nadson and R. S. Filippov (1925) and the American scientist, Muller (1927) were the first to show that ionizing radiations induce genetic changes in Drosophila flies and certain fungi. From that time onwards, numerous investigations made by Soviet and non-Soviet scientists have shown that various types of ionizing radiation - X-ray, γ-ray, neutron and others - are powerful means of bringing about genetic changes in all plants and animals, including Man. Hence, soon after the discovery of cosmic radiation, experiments were made designed to discover their genetic effects.

Soviet scientists were pioneers in these investigations. In 1936, test tubes containing Drosophila were placed in one of the stratostats launched in the Soviet Union. G. G. Frizen studied several generations of the progeny but did not detect hereditary changes. S. Pinkin and U. Sullivan of the USA, published in 1959 their results of experiments carried out with Drosophilae which flew for 30 hours in the gondola of an air ballon. Neither did they detect any hereditary changes in these insects.

However, these negative results cannot be considered final since in the above mentioned experiments the organisms were at an altitude not exceeding 23 km, where the pattern of the primary cosmic radiation differs considerably from that at higher altitudes. The genetic effect of cosmic radiation can be studied fully only under space-flight conditions. The beginnings of such investigations have been made by the experiments carried out on the second Soviet satellite.

It is well known that this satellite carried a number of species selected primarily for the purpose of genetic investigations: mice of two different strains; Drosophilae of two different strains, one of which had a very low, the other a very high, mutation rate (tendency to hereditary changes) under natural conditions; the spiderwort plant; varieties of pea seed; corn (maize), onion and nigella; actinomycete fungi - which have producers of antibiotic substances.

Immediately after landing cyto-genetic investigations were commenced with the purpose of detecting induced hereditary changes (mutations) in the above mentioned biological material. In addition, the influence of space-flight factors on the reproduction and development of these organisms was investigated. As only a short time has elapsed since landing of the second Soviet satellite these investigations are not yet complete. To carry out an adequate genetic analysis, at least two to three generations are required; for instance, for wheat, maize and peas, even if grown in hothouses, a considerable time is required. Only analyses of the genetic data from the rapidly reproducing species (Drosophilae and actinomycetes) are available; cytological analyses are not yet complete. From the other species (mice, plants and plant seeds) only data of the cytological investigations and observations on their reproductive rates and development are available.

What have these preliminary investigations shown?

Firstly, it can be generally stated that information of enormous importance has emerged. Space-flight conditions induce hereditary changes in various species and influence their development and reproduction.

The seeds of onions and nigella germinated much more quickly than the seeds of the controls. In the growing roots of seeds of peas, maize and wheat which had been in space, the mitotic rate was considerably increased. This increase in growth rate occurred particularly quickly in cultures of actinomycetes - which produce streptomycin. The growth of their colonies was accelerated sixfold.

As regards the genetic after-effects of space flights, the data can be summarized as follows.

For both Drosophila strains (those with low and those with high mutation rates under natural conditions) a slight but statistically reliable increase in the percentage of the dominant lethal mutations was observed (hereditary changes which appear in some of the first-generation progeny during the early stages of development); a considerably more pronounced effect was observed in the recessive sex-linked lethal mutations, which manifested themselves in a proportion of the progeny only from the second generation onwards. For both Drosophila strains, the frequency of appearance of these mutations was many times higher than in the controls. It is interesting that these phenomena were detected in the progeny which developed from embryos at various stages of development subjected to the effects of space flight. At present, cyto-genetic analyses are proceeding on the recessive lethal mutations in Drosophila which should reveal the nature of the chromosomal changes which have occurred.

No increase was observed in the percentage of chromosome recombinations of rootlets of onion and nigella seeds. In peas, maize and particularly wheat the cytological analysis of the cells of the growing points of the germinating roots revealed an appreciable increase in recombinations.

Thus, in various species stimulating as well as injurious effects of space flight were observed on the progeny and the processes of cell division in a generative and somatic tissue.

Primary cosmic radiation contains high-energy particles, the biological effect of which has not been clarified. It is known that protons have a much greater influence that X-rays or γ-rays on the genetic material. Therefore, in studying the effect of cosmic radiation on heredity, completely new and unexpected phenomenon should be anticipated.

In analyzing results it is necessary to bear in mind that in addition to cosmic radiation, other factors such as weightlessness, vibration, acceleration, etc. all exert their influence on the biological material. The effect of these factors on heredity has so far only been studied very little or perhaps not at all. It is known, for instance, that the combined effect of ionizing radiation and some other factors can change considerably the kind and the frequency of mutations. It cannot be ruled out that the detected genetic and cytological changes may be due to the combined effect of cosmic radiation and other factors that are specific to space flights.

The genetic effects discovered during the flight of the second Soviet satellite provided a basis for a completely new branch of science-space genetics. The obtained data indicate the potentialities of further genetic investigations associated with space flights. Determination of the genetic effects of space flights on some of the classical subjects of investigation (mice, Drosophila and certain plants) may prove very useful in assessing the biological dosimetry of the ionizing radiation which is encountered in space.

The revealed stimulating and mutagenic effect of space-flight conditions on various types of animals, plants and micro-organisms is of further importance since species of this type will accompany Man in his future space flights to ensure his oxygen and food requirement and perhaps solve the problem of the disposal of waste products of his metabolism.

Finally, investigations in this field will permit a better understanding of these space-flight effects and so enable the mechanism to be revealed by which disturbances in the structure of embryo cells cause hereditary changes of one type or another. If techniques can be worked out which will permit the differentiation between the influence of the individual factors (radiation, weightlessness, vibrations, acceleration, etc.) then the mechanisms causing genetic damage will be unravelled. This is one of the fundamental problems of modern biology.

Considering the entire material investigated so far, the conclusion can be made that no conclusive data have been obtained to prove that unfavorable biological effects are caused by radiation and other flight factors. However, it is necessary to bear in mind that these data are preliminary and relate only to the biological material, indices and methods of investigation applied in the experiments. A great deal of work has still to be done to complete the analysis of the available material. Furthermore, it is pointed out that the above conclusions apply only to specific flight conditions since the orbit of the second Soviet satellite was particularly favorable (it was located below the Van Allen radiation belt) and the duration of the flight was relatively short. It is also necessary to bear in mind that the intensity and composition of the radiation in the radiation belts fluctuates continuously in time and space within extremely wide limits. Major work is necessary before final conclusions can be drawn on the safety of space flights from radiation effects.

The above mentioned physiological, biochemical, cytological, histological, microbiological and genetic investigations carried out during flight of the second Soviet satellite were continued in the experiments made on the third Soviet satellite.

Investigations on the Third Soviet Satellite

In the same way as in previous experiments the basic medical and biological investigations carried out on the third Soviet satellite included:

1. The study of the biological effects of the main factors of space flight (overloading, long-duration effect of weightlessness, etc.) on living organisms;

2. The determination of the performance of life-support systems (regeneration, temperature-control, feeding, water-supply systems, etc.).

For solving medical and biological problems of space flights the applied methods and approach and the methods used are very important. In this respect, the experiments carried out in the third Soviet satellite are a new step in the investigation of cosmic space. In these experiments many new procedures, methods and biological materials were used appropriate to the biological material and the methods used. The radiotelemetry system provided very valuable information during a period of several days.

In the catapulted container, the sealed capsule of the satellite contained the two dogs, Pchelka and Mushka. This sealed capsule also contained five cages in which were two guinea pigs, two white laboratory rats, fourteen strain C_{57} black mice, seven hybrid mice derived from SBA and C_{57} and five mongrel mice. The capsule also contained six flasks with a high mutation strain of Drosophila, seven flasks with low mutation strains of Drosophila, six flasks with hybrid flies and two flasks with flies which were given with an additional protection of lead 5 g/cm^2 in thickness. The capsule also carried 5 g of pea seeds, 2 strains of wheat, 2 strains of maize, 4 strains of buckwheat and Windsor beans. A special container carried germinating onion seeds at various stages of development as well as moistened nigella seeds.

The satellite also carried several test tubes containing actinomyeites-streptomycin producers; capsules with human tissue in culture both inside the thermostat and outside the thermostat; six test tubes containing chlorella in a liquid medium; further sealed ampules of a bacterial culture of the intestinal rod type K-12 and KK-12 (in oxygen and without oxygen) and two varieties of phages (T_2 and T_4) which were carried in ebonite cartridges. Also investigated were: a solution of deoxyribonucleic acid (DNA); a culture of Hela tumor cells, pulmonary and amniotic tissue of man, fibroblasts and bone marrow. In a special thermostatically controlled container and in an unheated container there were three automatic bioelements with cultures of the bacilli concerned with butyric acid fermentation and one "Bios" automatic container with the ova and sperms of a frog.

To study the biological effects of cosmic radiation the following selection of enzymes was carried on the satellite:

a) Pepsin, trypsin, alkaline phosphatase, catalase, peroxidase, ribonucease;

b) Homogenate of seed buds of wheat;

c) A preparation of cell nuclei (wheat);

d) A preparation of cytoplasm of cells (wheat);

e) Different strains (ordinary cyphomandra and plantain) of tobacco mosaic virus in aqueous solution and ammonium sulfate;

f) Influenza virus (cultured on different tissues).

In the process of preparing the experiment, methods of investigation were perfected as well as monitoring instrumentation. Also, an extensive series of laboratory experiments were carried out in which the influence of individual factors on the state of the living organisms was studied.

The dog, Pchelka - a two-and-a-half-year-old female - of light color with reddish spots, short-haired, weighing 5 kg 900 g, 33 cm high and 50 cm long.

The dog, Mushka - four-year-old, female, light color, fluffy, long-haired, weighing 5 kg 600 g, 25 cm high, 55 cm long.

Both dogs passed the preliminary examination, withstood the training and were subjected to pre-flight routine in good time.

For recording the functions of the animals during flight, a special set of medical instruments was developed.

During the flight, the following physiological indices were recorded by means of various sensors: electromyogram; electrocardiogram; heart tone; seismocardiogram; respiratory movements of the thorax; body temperature; motor activity of the animals.

The radiotelemetry system transmitted to the receiving stations on Earth the following data which is of considerable importance in assessing physiological changes: barometric pressure, temperature and humidity in the space cabin. Data on the functioning of the life-support system were similarly transmitted.

In this experiment, study of the movement of the animals which remained for a longer period under conditions of weightlessness was continued and extended. The investigations were carried out by means of television apparatus and specially developed equipment for detecting movement, electromyograms (electrical changes in the muscles). Simultaneous movements of the neck of the animal were also recorded. This comprehensive information enabled an assessment to be made of the nature, the degree of changes in the animals' movements and the time required for adaptation to occur to the conditions of weightlessness.

Much attention was paid to studying the state of the cardiovascular and respiratory activity of animals under conditions of prolonged weightlessness. It is known that following the increase in the general level of functional changes during the period of powered flight of the rockets and satellites, there will be a decrease in these changes when conditions of weightlessness set in. The problems relating to the times required for normalizing the cardiovascular and respiratory functions to return to normal after the effects of acceleration, and the specific nature of the influence of weightlessness, requires further detailed study. Due to the prospects of carrying out long-duration space flights, this problem is not only of theoretical but also of practical importance.

On the third Soviet satellite large quantities of biological materials were used, particularly microbiological and cellular. The selection of the specimens, the development and testing of methods for testing biological material to space-flight conditions are important links in medico-biological investigations of space flight. New techniques have been developed and biological specimens can be successfully used in subsequent experiments since they provide new and more extensive possibilities of investigation.

Thus, exposure of microbiological and cellular material to space conditions should permit studying the influence of space-flight factors to be studied not only on highly-organized complete organisms but at the cellular and sub-cellular level. Application of micro-organisms and human cells in tissue cultures will probably enable investigating the influence of flight on elementary genetic processes to be studied.

A number of microbiological and cellular materials were flown into space repeatedly (intestinal rod KK-12 cultures, bacteriophage type T_2, Hela cancer cells, etc.) i. e., these cells had already been exposed to space conditions in the previous satellite and thus were exposed to space conditions twice. In some cases, the progeny of cultures which had been initially exposed to space-flight conditions were used. It is possible that such repeated exposure will enable physiological or genetic changes in cells to be detected which do not appear during a single exposure to space-flight conditions.

The enumerated number of microbes and cells used in the previous flight was substantially supplemented. In particular, besides the cancer cells in the tissue culture, normal cells of the human body were included; connective tissue fibroplasts; epithelial cells of respiratory tissue and human embryonic amniotic cells.

In spite of methodological difficulties, the use of tissue cultures is of great importance since it permits the influence of cosmic-space factors on cells to be studied which could not be determined in the actual body which possesses compensatory adaptations ensuring a rapid replacement of injured or dead cells by new ones. For this purpose a technique was developed which applies single-layer cultures on glass and permits the number of uninjured, injured and dying cells to be counted. The separation of the cells from the glass surface, changes in their staining characteristics and their ability to reproduce during subsequent cultivation were used in assessing cell injury and death. The technique of tissue culture also is valuable for studying genetic effects.

The third Soviet satellite also carried bone marrow of rabbits in a culture medium and two types of embryological specimens. It was intended to use these specimens for studying the initial stages of development of a fertilized egg, using, in particular, the ova and sperms of frogs. A special automatic device "Bios" (which has much in common with the bioelement AMN-1) was used to ensure mixing of the sperms and the ova (i. e., fertilization) at a predetermined time in accordance with the program of the experiment.

In addition to microbiological and cellular material, the third Soviet satellite carried deoxyribonucleic acid (DNA). This substance, which plays a major role in hereditary mechanisms, can undoubtedly be used to study the genetic conditions pertaining to space flights.

In the experiments with the third Soviet satellite lysogenic strains of intestinal rods (producing bacteriophages) were extensively carried out. Very small doses of ionizing radiation bring about a change in the genetic mechanism of the so-called lysogen bacteria, which manifests itself in alterations in the hereditary characteristics. In the experiments with lysogen bacteria, the ability of these bacteria to increase the production of bacteriophage in the culture medium was used as an elementary genetic test of the effect of ionizing radiation. Consequently, this is a particularly sensitive biological index for the given biological material. Furthermore, a part of the microbiological and cellular material was placed under an increased partial pressure of oxygen which is known to intensify their sensitivity to ionizing radiation.

Protecting some biological material (for instance, Drosophila flies) by means of an additional protective layer of lead will help in the investigation of those components of cosmic radiation which have the greatest biological (genetic) effect.

In the same way as in the earlier satellite, so-called AMN bioelements were carried, i. e., instruments which were developed specially for recording automatically the life function of micro-organisms. The AMN bioelements transmit to the ground information on the functions of microbes and so make possible the formulation of the necessary conditions for the existence of these living cells in regions of space where so far it has not been possible to introduce large animals which require considerable reserves of food and oxygen, depending on the flight duration.

In view of their very small dimensions and weight, these instruments can be fitted in large quantities on a single satellite and then switched-on, one after the other, so as to obtain the characteristics pertaining to various parts of the orbit. The information obtained by means of these bioelements carried on the third Soviet satellite (in a thermostat as well as in unheated containers) proved that they functioned satisfactorily in accordance with the experimental program. No deviations from the normal were observed in the function of these micro-organisms (bacteria-producing butyric acid fermentation).

Thus, the biological experiments carried out in the third Soviet satellite represent a new and important contribution to the development of space medicine and biology. As a result of these experiments, the following basic information was obtained:

1. The performance of a large number of systems designed to ensure the maintenance of life on spaceships was determined.

2. The influence of space-flight factors on a number of physiological indices was studied, many of these for the first time.

3. New methods were developed, tested and applied to a wide range of biological materials under space-flight conditions and much new information was obtained about the biological activity of some of this material.

The information accumulated so far indicates that the inclusion of biological specimens on satellites and spaceships can contribute to solving the problems which are posed as to the biological conditions that exist in various zones of cosmic space.

Various organisms can be used as test systems for the possible harmful effects in space. However, the appreciable differences in the sensitivity of these materials to that of the various organs and tissues of the human body must be borne in mind.

When interpreting the biological and genetic information so far obtained from the satellites, it is necessary to bear in mind that the organisms and external medium form an entity. Hence, it is important to aim not only at detecting the inherited changes that occur but also the purely adaptive phenomena which always accompany the process of evolution wherever it may occur.

Further biological investigations of cosmic space, with the resultant accumulation of new information and its correct theoretical analysis are important conditions for the successful solution of the extremely difficult and major problems facing space biology and medicine.

Summary

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The maintenance of life conditions is discussed with special reference to the second Soviet satellite. During the flight the proportion of oxygen in the air of the cabin could be maintained at 21 to 24 percent, whereas the relative humidity rose from 37 to 47 percent. The temperature ranged from 16 to 19° C. Water and food were provided together in a mixture solidified with agar in order to facilitate automatic dispensing in conditions of weightlessness. This was carried out twice daily by command signals from the Earth. Telemetric recording of the physiological parameters of the dogs, Belka and Strelka, during space flight showed the occurrence of tachycardia as a result of acceleration, noise and vibration, and there was also a rise in the respiration rate; a return to normal preflight values occurred during the condition of weightlessness. Movements of the animals were observed by television cameras and by strain gauge sensors mounted in the harness. No abnormalities were observed in the behavior of the animals after return to Earth or during the following 3 months. It was concluded from the experiments carried out in the second satellite that dogs could readily be accustomed

to space-flight conditions. Genetic changes were noted in the progeny of actinomycetes, plant seeds and fruit flies after return from space flight.

The third space satellite contained 2 dogs (Pchelka and Mushka), 2 guinea pigs, 2 rats, 26 mice, fruit flies, seeds and other biological materials which were included in order to study the effects of cosmic radiation. The results are not described.

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